

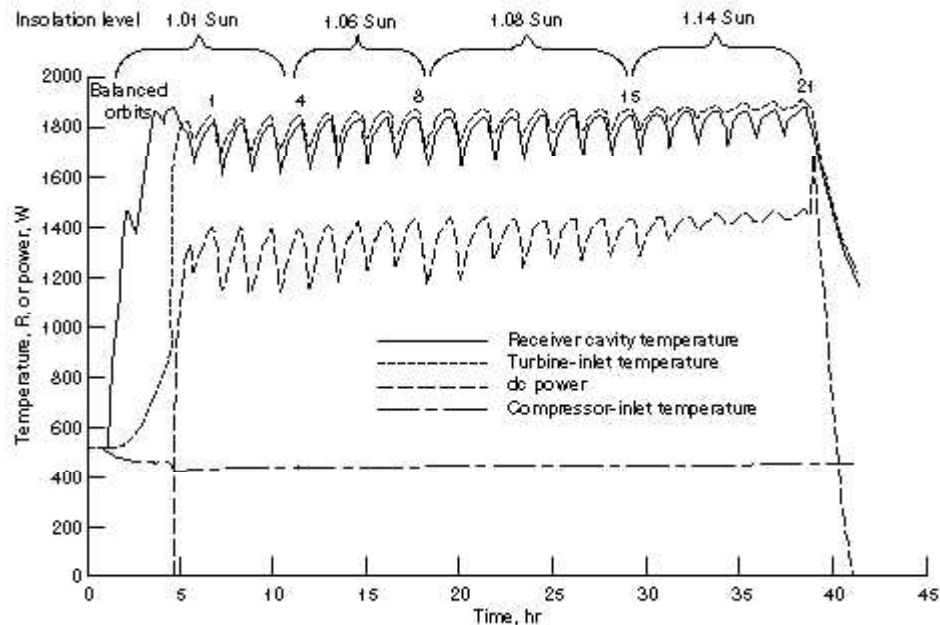
## 2-kW Solar Dynamic Space Power System Tested in Lewis' Thermal Vacuum Facility

*Solar dynamic system installed in tank 6.*

Working together, a NASA/industry team successfully operated and tested a complete solar dynamic space power system in a large thermal vacuum facility with a simulated sun. This NASA Lewis Research Center facility, known as Tank 6 in building 301, accurately simulates the temperatures, high vacuum, and solar flux encountered in low-Earth orbit. The solar dynamic space power system shown in the photo in the Lewis facility, includes the solar concentrator and the solar receiver with thermal energy storage integrated with the power conversion unit. Initial testing in December 1994 resulted in the world's first operation of an integrated solar dynamic system in a relevant environment.

Acceptance testing of the solar dynamic system was accomplished in only 3 months, from December 1994 through February 1995, by an industry team led by AlliedSignal Inc. with support from Lewis. Over 2 kW of electrical power was produced on February 17, 1995, while the system was operating at 52,000 rpm with a turbine inlet temperature of 1063.5 K (790.5 °C) and a compressor inlet temperature of 270.2 K (-2.8 °C). AlliedSignal's acceptance testing involved about 40 hr of power operation with 10 orbits, including 5 successful ambient starts with 1 hot restart. Operation of the turboalternator-compressor was shown to be within acceptable limits. The 2-kW solar dynamic system was turned over to NASA in March 1995.

The solar dynamic system was tested for over 365 hr of power operation, ranging from 300 W to 2.0 kW, including 187 simulated low-Earth orbits, 16 ambient starts, and 2 hot restarts. NASA characterized the solar dynamic system and evaluated various analytical models over a variety of solar insolation levels, speed conditions, orbit periods, and engine inventories to support the Joint U.S./Russian 2-kW Solar Dynamic Flight Demonstration project. System testing showed that an overall system efficiency (conversion of sun into user energy) was in excess of 15 percent, whereas the engine cycle efficiency was over 26 percent. Foil bearing technologies, developed in the 1970's, were successfully demonstrated with 48 start/stops on the turboalternator-compressor. Finally, the solar dynamic space power system demonstrated orbital startup, transient and steady-state orbital operation, and shutdown in a relevant space environment.



*Data showing startup, multiple orbits, and shutdown of solar dynamic system.*

The graph shows an example of data from an operational solar dynamic system (receiver and power conversion unit), including the average receiver cavity temperature, the turbine-inlet temperature, the compressor-inlet temperature, and the dc power output. This test was conducted over a 40-hr period with the turboalternator-compressor operating at 48,000 rpm. It illustrates an orbital startup, transient and steady-state orbital operation, and a shutdown. The turboalternator-compressor was operating at 48,000 rpm throughout the test, except for the shutdown at 52,000 rpm. The solar simulator provided four different insolation levels--1.01, 1.06, 1.08, and 1.14 suns ( $1.37 \text{ kW/m}^2 = 1 \text{ sun}$ )--resulting in four steady-state orbital cases during the 93-min orbit. Balanced orbital operation was achieved on orbits 4, 8, 15, and 21. The first three cases are in a sensible heat receiver (where the canister phase-change material does not melt), which resulted in large temperature (137.2 K) and power (138 W) fluctuations. The fourth case, a latent heat receiver state, resulted in a marked reduction of temperature (19.4 K) and power (49 W) fluctuations during the orbit, which are in good agreement with analytical predictions. For this off-design point, overall "system" efficiency (conversion of sun into user energy) was in excess of 14 percent and the engine efficiency was about 24 percent.

The collective efforts of the NASA/industry team resulted in the first full-scale demonstration of a complete space-configured solar dynamic system in a large thermal vacuum facility with a simulated sun. Initial operational and performance data have demonstrated a solar dynamic power system with sufficient scale and fidelity to ensure confidence in the availability of solar dynamic technology for space. Studies have shown that solar dynamic power with thermal energy storage can provide continuous electric power in near-Earth orbits with significant savings in life-cycle costs and launch mass when compared with conventional photovoltaic power systems with battery storage for providing continuous electric power in near-Earth orbits. Testing has demonstrated that

the solar dynamic technologies developed by NASA programs during the past 30 years are available for near-Earth orbit applications. Applications include potential growth for the international space station, for communication and Earth-observing satellites, and for electric propulsion.

An aerospace Government/industry team worked together to successfully demonstrate solar dynamic power for space in a way that was "cheaper, faster, and better." The solar dynamic ground test demonstration program was completed in early 1995, ahead of schedule and under budget. The Government/industry team delivered the 2-kW solar dynamic system demonstration as promised.

## **Bibliography**

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